NASA Project, EOS Validation, Contract S-97899-F, Progress Report

FLUXNET: Unifying a Global Array of Tower Flux Networks for Validating EOS Terrestrial Carbon, Water and Energy Budgets.

Project Officer: Dr. David Starr
Code 913, Bldg 33, Rm C-308
NASA Goddard Space Flight Center
Greenbelt, MD 20771
starr@climate.gsfc.nasa.gov

Period of Activity: Oct. 1, 1997 to June 30, 1999.

Principal Investigator:
Dennis Baldocchi

Project Postdoctoral Fellow:
Eva Falge

Co-Investigators: Steve Running, David Hollinger, Richard Olson, Riccardo Valentini, Helen Cleugh

May 20, 1999

EXECUTIVE SUMMARY

The FLUXNET project commenced October, 1997, under the auspices of the EOS Validation Program. The overarching goal of FLUXNET is to provide an infrastructure for the synthesis and analysis of long-term carbon, water and energy flux data, that is being acquired world-wide by various regional flux networks. Information compiled by this project will be used to validate algorithms on land surface products and process that will be derived by the MODIS 12, 15, 16 and 17 activities.

During the first 18 months of operation, the FLUXNET project had numerous accomplishments. These include:

1. The FLUXNET Web page created and is on-line, http://www-eosdis.ornl.gov/FLUXNET/index.html

2. The Second FLUXNET International Workshop was convened, Polson, MT, June 3-5, 1998.

3. A FLUXNET postdoctoral fellow was recruited and hired (Dr. Eva Falge).

4. A FLUXNET/AmeriFlux data synthesis on interannual patterns and controls of net ecosystem CO_2 exchange is underway.

5. FLUXNET is a key theme of BAHC/IGBP (Biosphere Aspects of the Hydrological Cycle Project of the International Geosphere-Biosphere Program).

6. Thematic paper was written and is in press:

Running, S.W., D.D. Baldocchi, D. Turner S.T. Gower, P. Bakwin and K. Hibbard. 1999. A global terrestrial monitoring network, scaling tower fluxes with ecosystem modeling and EOS satellite data. *Remote Sensing of the Environment*. (in press).

7. Regional network inter-calibration activities began. The first study was conducted in Sweden.

8. A European FLUXNET office was established at the Joint European Research Institute, Ispra, Italy.

NARRATIVE

Terrestrial ecologists need to assess ecosystem metabolism and water use and ecosystem structure on the time and spaces scales at which the ecosystem operates. This involves evaluating canopy- to continental-scale fluxes of carbon dioxide, water and energy over the course of a year. At discrete points on the globe, this task can be accomplished by micrometeorological measurements of air-surface gas and energy exchange. To scale this information across landscapes and continents, we need to combine tower data with estimates of mass and energy exchange, derived from satellite based sensors.

The FLUXNET project is a new and unique tool to study and quantify ecosystem metabolism. It consists of a global array of micrometeorological towers that are measuring flux densities of carbon dioxide, water vapor and energy between vegetation and the atmosphere on a continuous and long-term basis. Essentially, the FLUXNET project is a network of regional networks.

Information compiled by the FLUXNET project will be used to validate remote sensing algorithms that will be generated by the MODIS instrument on the new Terra satellite. Products to be generated by the MODLAND group and validated by FLUXNET measurements include leaf area index, fraction of photosynthetically active radiation, evaporation and net primary productivity.

The FLUXNET project consists of a Project Office and a Data Archive Office. The project office consists of the Principal Investigator, a dedicated postdoctoral scientist and a science advisory panel. The FLUXNET project office is responsible for synthesizing mass and energy flux data, creating value-added products and organizing workshops. The Data Archive Office is funded as a complementary project. Richard Olson of Oak Ridge National Laboratory is Principal Investigator of that project. The Data Archive Office is responsible for coordinating and operating the FLUXNET Data and Information system (FLUXNET DIS). Data on meteorological conditions, mass and energy flux densities and stand characteristics are being compiled and converted in a common formats with known quality, and archived. The Data Archive Office will maintain a Web page for communication and data exchange.

The goals of the FLUXNET are to:

1) quantify the spatial differences in carbon dioxide and water vapor exchange rates that may be experienced within and across natural ecosystems and climatic gradients;

2) examine temporal dynamics and variability (seasonal, inter-annual) of carbon, water and energy flux densities; such data should allow us to examine the influences of phenology, droughts, heat spells, El Nino, length of growing season and presence or absence of snow on canopy-scale fluxes;

3) understand the biological and climatic processes that control canopy-scale CO_2 and water vapor exchange; quantify the variations of carbon dioxide and water vapor fluxes due to

changes in insolation, temperature, soil moisture, photosynthetic capacity, nutrition, canopy structure and ecosystem functional type;

With data at hand, we have the ability to test:

1) a suite of biophysical, biogeochemical and biogeographical models that compute carbon balance and hydrological;

2) improve the ability of models to simulate seasonal dynamics (e.g., improve algorithms that predict phenological switches associated with the initiation of budbreak, the expansion of leaves and the initiation of leaf senescence; improve algorithms that predict the effects of soil moisture deficits on photosynthesis, stomatal conductance and transpiration);

3) quantify links between surface fluxes and remote sensing products. Data from the FLUXNET project will be used by the MODIS Land Surface team to validate various algorithms that will be used assess various land surface products.

STATUS OF FLUXNET AND RECENT ACTIVITIES

At present about 80 tower sites, scattered across the globe, are members of FLUXNET. The network spans a spectrum of vegetative functional types, climates, countries and continents. Tower sites are operating as for north as the arctic tundra and the boreal taiga and as far south as the tropical forest. The majority of sites are in the temperate regions, where most research institutes are located. There, temperate conifer and broadleaf forests, crops, grasslands and savanna systems most are represented. The largest gap in the network occurs in Africa and the boreal forest of Siberia. However, campaign-mode studies are being conducted in these two regions.

The FLUXNET project does not fund tower sites directly, but depends upon institutional support associated from various national and international government agencies. The AmeriFlux Network is funded by a consortium of American and Canadian agencies. The main patrons include NIGEC, DOE, NASA, NOAA, Canadian National Research Council. The EUROFLUX and MEDEFLU networks are funded by the European Commission Directorate General XII "Environment and Climate Programme". Networks in Japan and Australia are funded by their national governments. The array of sites in Brazil is funded by NASA, the Brazilian government and the European Commission.

The EUROFLUX was the first regional CO_2-water vapor flux measurement network in operation. It was funded in 1995 and measurements were initiated in 1996. This regional network concentrates on forest ecosystems and uses a standard set of instruments and software. This project has just completed a three-year funding cycle. Sites funding within the EUROFLUX network are up for funding renewal at the writing of this report. The Europeans hope to attain financial support through a new European Carbon Initiative.

The AmeriFlux Network was organized during the fall of 1996. However, some participants have data as far back as 1990. The AmeriFlux network covers a wider range of ecosystems than does its European partner, with sites over grassland, crops, tundra and tropical forests as well as temperate and boreal forests. The AmeriFlux network also includes measurements on one very tall (500 m) broadcast tower. This study allows information between surface fluxes and boundary layer dynamics to be obtained. All AmeriFlux participants use the eddy covariance method, but no standard set of instruments or software is imposed. Participants use open and closed path CO2 sensors. Tests show that open and closed path infrared gas analyzers yield similar fluxes. To ensure quality control and intercomparibility of data, a standard set of reference instruments is circulated among the partners. This philosophy is adopted by the FLUXNET project and is funding the travel and execution of comparative calibration measurements at representative European sites.

New regional flux networks are being organized in Japan (JapanNet), Australia (Ozflux) and Brazil (LBA, Large Scale Biosphere Atmosphere Experiment in Amazonia). In Asia 5 towers will be operated in Japan and 6 in Thailand and Indonesia. About 9 sites are anticipated to operate in Brazil.

The FLUXNET Project Office and Data Archive Office are in close contact with one another. Over the past year, we've met regularly on a bi-weekly basis to plan strategies for designing the web page, to discuss content to be acquired by the network and presented on the network. We have also discussed the value-added products that have been produced.

At this juncture, we are starting to plan the next FLUXNET meeting (tenatively May/June, 2000) and are trying to make connections between the modeling and measurement communities to use FLUXNET data for testing the next generation of ecosystem models. The FLUXNET office is working in close association on data and modeling synthesis activities being conducted within the AmeriFlux and EUROFLUX communities.

A. FLUXNET Workshop

The major activity of FLUXNET was its convening of the Second International FLUXNET workshop in Polson, MT, June 3 to 5, 1998. About 70 scientists from across the world (United States, Canada, Japan, Australia, Italy, United Kingdom, France, Netherlands, Germany, Belgium, Sweden, Finland, and Denmark) attended. These scientists represented the EUROFLUX, AmeriFlux, OzFlux, JapanNet and the Amazonian LBA projects, the remote sensing, biogeochemical and eco-physiological modeling communities and supporting government agencies.

The programmatic objectives of the workshop included organizing the regional networks into a global network, promoting communication and cooperation among the regional networks and the presentation of recent measurement and the discussion of future experimental and modeling plans.

The scientific objectives of the workshop were to discuss new scientific findings across several broad topics. These topics included: 1. cross biome flux inter-comparisons; 2. Inter-intra annual variation of carbon and energy fluxes; 3. assessing tower flux footprint and regional scaling; and 4. SVAT Modeling development and testing.

1.Across Biome Comparisons

Many key questions were identified that could be asked with data from across major biomes. Major issues were whether or not leaf-level gas exchange relations hold at the ecosystem level. Which independent variables define NEE and how it varies across biomes? How is net ecosystem carbon exchange (NEE) partitioned into gross carbon exchange (GEE), autotrophic and heterotrophic respiration (R_a and R_h) across biomes? Do we obtain the same NEE over different ecosystems for the same reason or is the partitioning among GEE, R_a and R_h different? Do the components resulting in NEE differ depending on the time scale for which they are examined? Are relationships on daily, seasonal and yearly time scales the same?

Suggestions for driving independent variables driving NEE included length of growing season, meteorological variables (such as sunlight, cloudiness, temperature, precipitation, humidity), leaf area index, leaf nitrogen, stand density and stand age.

In regard to continual and future operation of the network, relevant questions raised at the workshop included: is the range of sites wide enough to draw robust relations between climate, functional types and other environmental factors? Do the available sites cover gradients of N availability, soil organic matter, chronosequences, or disturbance regimes? Are all major ecosystem types considered? This issue will have impact on future network design and expansion. We need information at the extremes of the scale to draw statistically robust relations, e.g. very productive (e.g. wetlands, humid temperate forests) and very unproductive (e.g. desert) ecosystems.

2. Inter- and intra- annual variation

Questions discussed by the participants were: how does NEE, its components, and LE vary seasonally and interannually at given sites? Do these patterns vary by biome or functional type, or is there a universal pattern? What are important driving variables of year to year differences in NEE? Preliminary data presented at the workshop are showing the importance of length of growing season, cloudiness, absence or presence of snow, and drought.

To understand year to year differences in carbon fluxes there is a need to understand the constituent components of canopy carbon dioxide fluxes, photosynthesis and soil/root respiration. For example, if there is warming and NEE decreases, is it because soil respiration increased or photosynthesis decreased? The response of photosynthesis to temperature is non-linear, the response may depend on the absolute temperature. It will also depend upon how the soil and above ground pools are perturbed. Warm years may reduce NEE if drought is associated with warmer years. Or warm years may increase NEE if the growing season is lengthened.

Many areas of future research were identified to understand year to year differences better. We need to quantify phenology and the dynamics of leaf area at each site. This can be accomplished with measurements of light transmission, reflected PAR and litter fall. Soil respiration needs to be assessed routinely. Information on vegetation composition, its age structure and how it has evolved since disturbance are other types of desired data. Relatively long term records, plus information on nitrogen inputs and pools are needed to assess potential time lags and phase shifts between NEE and driving variables.

3. Footprint and regional scaling

To assess the temporal pattern and integration of NEE the role of changing wind direction, footprint dimensions and forest characteristics were identified as issues that needed investigation.

Some confusion with the term "footprint characterization" was noted. The micrometeorological definition of footprint describes the dimensions and behavior of the surface source area of influence for a tower-based flux measurement. The characterization of the source area or footprint involves a detailed inventory of the vegetation and soils contained in the source area, to the detail need for any given SVAT model, as used by carbon flux modelers. It was also noted that the needs for various SVAT models may not be identical. It was agreed upon to let the micrometeorologists do the "footprint modeling", the ecologists do the "footprint vegetation characterization". Refined estimates of net ecosystem exchange from complex and multi-species sites will need to consider wind roses and footprint distributions when computing such sums.

4. SVAT Modeling development and testing

The modelers and experimentalists started planning to collaborate to test, validate and develop comprehensive SVAT models for mutual learning, to enhance insights and enable value-added product delivery. Experimentalists will provide meteorological and flux data and modelers will take primary responsibility for creating data files for models. They will fill gaps and make data available to network. The modelers propose to start the model testing exercise with several test cases. The sites which have extensive data bases that are suitable for model testing include BOREAS sites (aspen and old black spruce), AmeriFlux grassland, the tall-tower, mixed woodland, Harvard Forest, Howland, Oak Ridge, various EUROFLUX sites and the Manaus site in Brazil. It was proposed that three model classes be examined. These include soil-vegetation-atmosphere transfer (SVAT), semi-empirical site based or intensive models and biogeochemical cycling models.

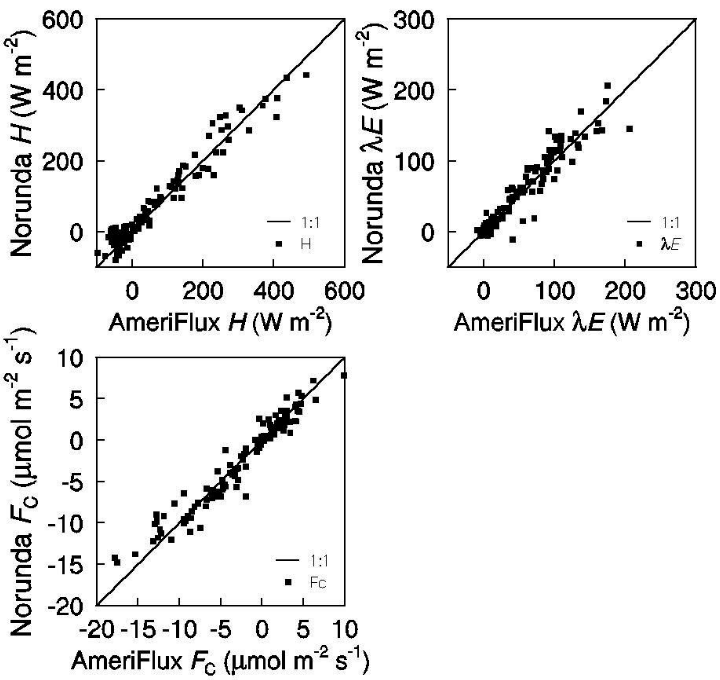
NETWORK INTERCOMPARISON

One of the goals of FLUXNET is to ensure that the results reported by different flux networks are comparable. This is carried out by transporting the AmeriFlux roving (“Gold”) system to selected FLUXNET sites. The AmeriFlux “Gold” system is used as a reference system within the AmeriFlux network and now FLUXNET. This year the roving system went to the

EUROFLUX site in Norunda, Sweden (May 23 - June 5, 1998) and the only operating station in the OZFLUX network, Twizel, New Zealand (March 1 - 10, 1999).

Norunda tower site

This site is located in central Sweden and is dominated by 100-year-old Norway spruce and Scots pine. It is administer by Dr. Anders Lindroth, Department of Physical Geography, Lund University, Sweden. Fluxes from this site are typical of coniferous forest although nocturnal respiration appears to be high. The slope of the regressions of fluxes between the two stations (AmeriFlux system as independent variable, EUROFLUX system dependent variable) for sensible heat (*H*), latent heat (λE), and carbon dioxide (F_C) were within 5%, 1%, and 9%, respectively, of the 1:1 line (see below). The intercept of these regressions were acceptable close to zero and the coefficients of variation (r^2) ranged between 0.91 and 0.95. These results are very good and superior, in fact, to the level of agreement generally found between the "Gold" system and the various AmeriFlux sites.



Twizel

This site is a degraded sheep pasture in the McKenzie Basin of New Zealand. It is operated by Dr. John Hunt, Landcare Research, Lincoln, New Zealand. The tower is 3 m tall and our results indicate that fluxes from the vegetation are low. Data have not been received from the New Zealand researchers, so the final comparisons can not yet be made.

PRELIMINARY DATA RESULTS

Temporal Dynamics

One of the greatest strengths of the networks is to quantify diurnal and season patterns of net ecosystem CO2 exchange by biome. At a given sites interannual variabilty in net ecosystem carbon exchange are modulated by length of growing season, cloudiness, absence or presence of snow, soil temperature and drought. Among sites key factors causing differences in NEE include plant habit (woody versus herbaceous, evergreen, deciduous), soil carbon stores, latitude (mean annual temperature). Figures 3 and 4 show annual patterns of NEE for deciduous and conifer forests from the AmeriFlux and EUROFLUX networks.

Figure 3. Seasonal Variation of NEE at various Deciduous Forest sites.

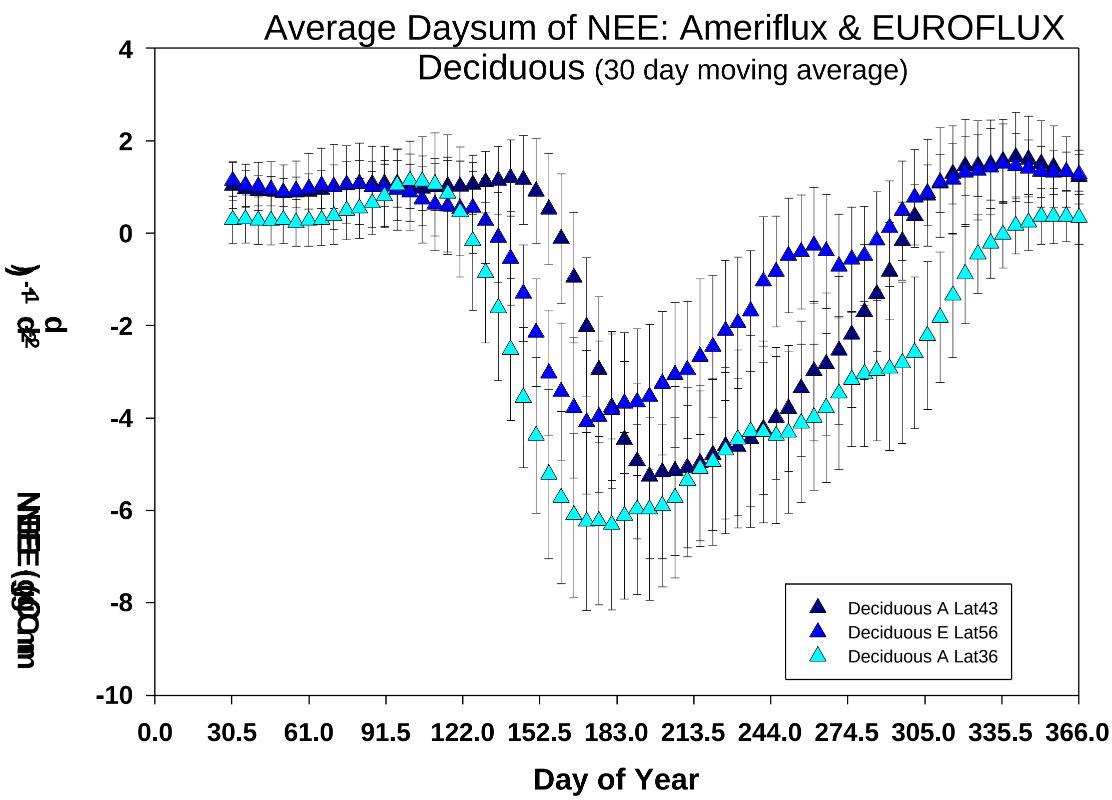
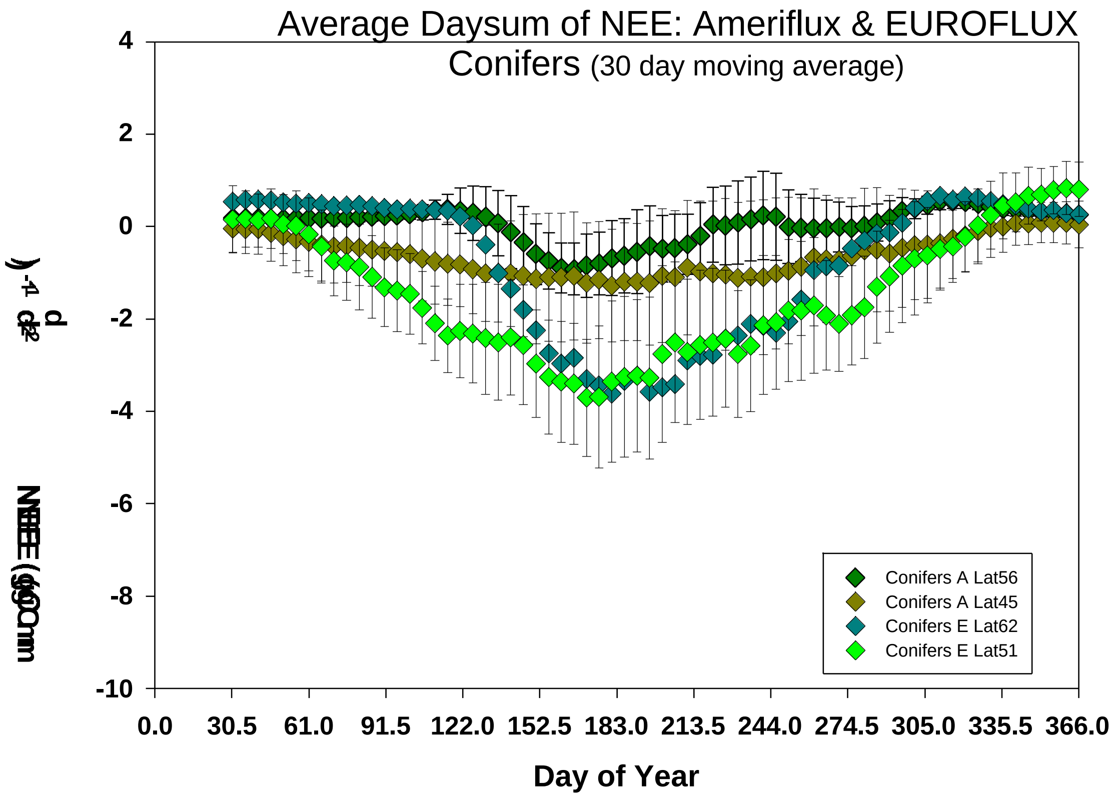


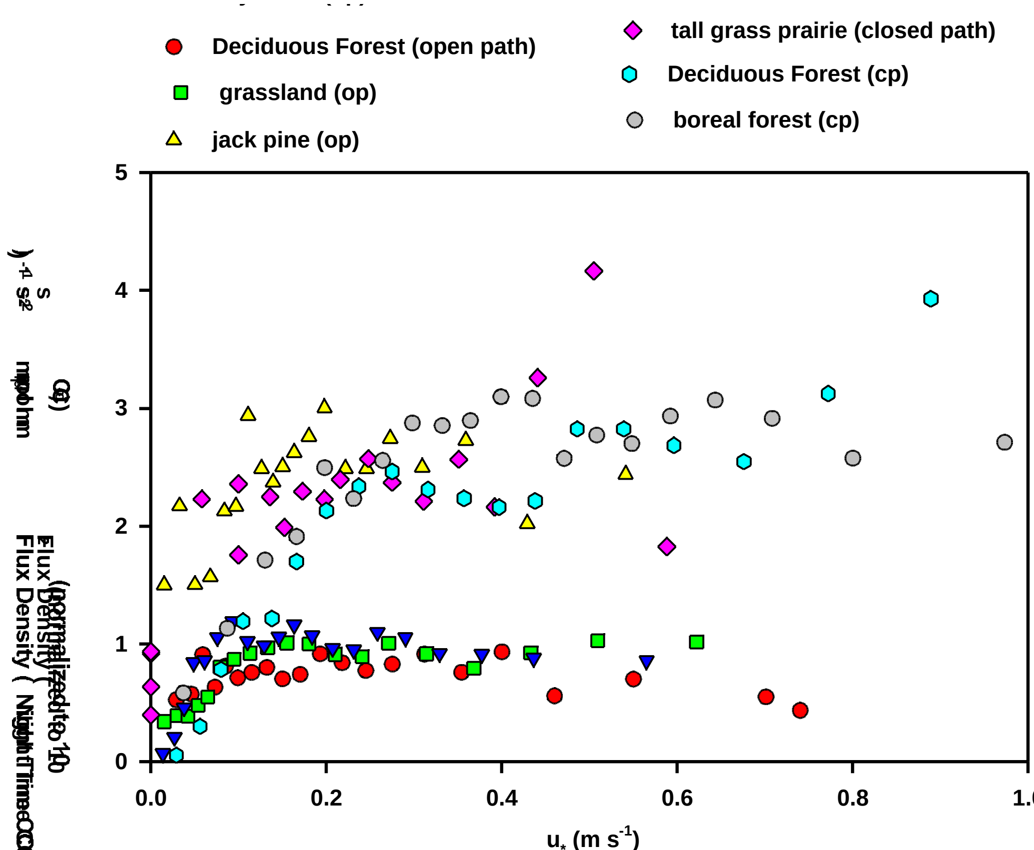
Figure 4 . Seasonal Variation of NEE at various conifer forest sites



Nighttime and Complex Terrain Bias Errors

Annual sum of carbon exchange can be biased by underestimates of canopy respiration during nighttime periods. Efforts are underway to examine whether an empirical correction can be used, by normalizing NEE to high friction velocity values, or by incorporating additional terms, derived from the conservation of mass equation, due to advection. Figure 5 shows the impact of turbulent mixing on nighttime flux measurements at several EUROFLUX and AmeriFlux sites.

Lee (1998) reports on a new correction that accounts for vertical advection. We are in the process of evaluating this relation for a temperate forest. Preliminary result suggest that the vertical advection term does not correct for the leaking of CO2 out of the vertical column over a site in complex terrain.



amerif~1/neeustr.spw
4/23/99

Gap Filling

It is impossible to measure eddy fluxes 24 hours a day, 7 days a week, 52 weeks per year. During the course of a year on an average 30 % of NEE, and 24 % of latent heat flux (LE) data are missing or had to be rejected. These numbers are based on examining 16 sites and several years of data from the EUROFLUX and Ameriflux projects. Missing periods are due to system or sensor breakdown, off-scale or spikes in the raw data, high anemometer rotation angles, or missing data for correction terms (pressure, air temperature, profile measurements for CO_2 or heat storage). Rejection occurs when stationarity tests or integral turbulance characteristics fail, examination of the foot-print of the flux indicates a different source area, biological (as leafless periods) or physical constraints apply (as available energy or energy balance closure). In addition, for some sites rejection probability is higher during nighttime, jeopardizing potentials to extrapolate existing data during that period. Especially at night the strategies of rejecting data vary a lot. There is no consensus on correction for friction velocity during night for instance, but depending on the site it can cause major offsets in the resulting annual sum (up to several hundred grams of carbon).

Gap filling methods include linear interpolation, mean daily courses of previous periods, and semi-empirical gap filling. Linear interpolation is often being used for small gaps (2-3 half-hourly means missing), and especially useful to complete meteorological variables as temperature or relative humidity. Mean daily courses based on half-hourly or hourly data differ in the length of the time interval, which is used to calculate the mean daily course (usually 4 to 15 days). Especially during changing weather, bud-break or leaf-fall periods the filling results depend strongly on the length of the chosen time interval. Semi-empirical gap filling on the basis of measurements during low atmospheric stability preserves for instance the response to temperature and photosynthetic photon flux density as found in the data. Responses are described by average values for assorted environmental conditions or use saturation functions for the light response, optimum curves for the temperature response of light-satured capacities and exponential functions for nighttime fluxes. Major differences result from the "right" assignment of seasonal periods, i.e. periods where responses are assumed to be constant. In some cases consideration of additional meteorological factors (as vapor pressure deficit, isotropy of radiation or drought), and also human activities (as mowing of rangeland or harvesting of crops) might help improving the results.

Gap filling methods depend crucially on the data basis used in the parameterization of the filling algorithms. So a better documentation of rejection criteria would not only be useful in interpreting gap periods, decision which filling strategy is most applicable, investigating, possibly reducing rejection causes, but provide comparability of the filled-in data. The results reported here re-emphasize the importance of methods standardization during the data post-processing phase.

INTERNATIONAL ROLES

The FLUXNET project and its products are rapidly being recognized by the international community and are being incorporated into several international projects. At present FLUXNET is a Key Theme of the of BAHC/IGBP (Biospheric Aspects of the Hydrological Cycle/International Biosphere-Geosphere Program). It is also being integrated into the GCTE/IGBP (Global Change and Terrestrial Ecosystems) as Task 1.4.1: Integrating Ecosystem Physiology into Regional and Global Ecosystem Models. Recently, FLUXNET was asked to be incorporated into the International Biodiversity Observation Year Program.

PUBLICATIONS, MEETINGS AND TALKS

Peer Reviewed Publications

Canadell, J., H. Mooney, D. Baldocchi, J. Berry, J. Ehleringer, c. Field, T. Gower, D. Hollinger, J. Hunt, R. Jackson, S. Running, G. Shaver, S. Trumbore, R. Valentini and B. Yoder. 1999. Carbon metabolism of the terrestrial biosphere. *Ecosystems* (submitted)

Baldocchi, D.D., F.M. Kelliher, T.A. Black and P.G. Jarvis. 1998. Climate and vegetation controls on boreal zone energy exchange. Global Change Biology. (submitted)

Running, S.W., D.D. Baldocchi, D. Turner S.T. Gower, P. Bakwin and K. Hibbard. 1999. A global terrestrial monitoring network, scaling tower fluxes with ecosystem modeling and EOS satellite data. Remote Sensing of the Environment. (in press).

Eugster, W., W.R. Rouse, R. Pielke, Sr., J. McFadden, D.Baldocchi, Y. Vagonov, T. Kittell, F.S. Chapin, G. Liston and P. Vidale. 1998. Energy balance feedbacks to climate: integration and circumpolar extrapolations. Global Change Biology (submitted).

Malhi, Y., D.D. Baldocchi and P.G. Jarvis. 1999. The carbon balance of tropical, temperate and boreal forests. Plant, Cell and Environment. (in press).

Steffen, W., I. Noble, J. Canadell, M. Apps, d. Schulze, P. Jarvis, D. Baldocchi, P. Ciais, W. Cramer, J. Ehleringer, G. Farquhar, C. Field, A. Ghazi, R. Gifford, M. Heimann, R. Houghton, P. Kabat, C. Korner, E. Lambin, S. Linder, J. Lloyd, H. Mooney, D. Murdiyarso, W. Post, C. Prentice, M. Raupach, D. Schimel, A. Shvidenko, R. Valentini. 1998. The terrestrial carbon cycle: implications for the Kyoto protocol. ***Science***. 280: 1393-1394

Book Chapters

Kelliher, F.M., J. Lloyd, D.D. Baldocchi, C. Rebmann, C. Wirth and E-D. Schulze. 1999. Evaporation in the boreal zone during summer: physics and vegetation. (submitted)

Raupach, M.R., D.D. Baldocchi, H. Bolle, L. Dumenil, W. Eugster, F. Meixner, J. Olejnik, R. Pielke, Sr., J. Tenhunen, R. Valentini. 1998. How is the Atmospheric coupling of land surfaces affected by topography, complexity in landscape patterning and the vegetation mosaic? In: Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. Dahlem Konferenzen

Valentini, R., D. Baldocchi, J. Tenhunen. 1998. Ecological Controls on Land Surface Atmospheric Interactions. In: Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. Dahlem Konferenzen.

Newletters

Valentini, R., D.D. Baldocchi, R. Olson. 1999. FLUXNET: a challenge that is becoming a reality. Global Change Newsletter. (in press)

Valentini, R. D.D. Baldocchi, S. Running. 1997. The IGBP-BAHC global flux network initiative (FLUXNET): current status and perspectives. Global Change Newsletter. **28**, 14-16.

Activities

Running, R, Baldocchi, D., Convened Polson FLUXNET Workshop, Polson, MT, June, 1998.

Meetings Attended Representing FLUXNET

Talks Given:

Baldocchi, D. Eddy covariance measurements and long term flux networks. GTCE/BASIN (Biosphere Atmosphere Stable Isotope Network) Workshop. Snowbird, UT. Dec. 7-10, 1997.

Baldocchi, D. FLUXNET Overview. ISLSCP/BAHC Workshop, Paris, France, April, 1998.

Baldocchi, D. On Measuring Carbon Dioxide Fluxes over Complex Terrain. FLUXNET Workshop. Polson, MT, June, 3-5, 1998.

Baldocchi, D. Flux Measurements and Flux Networks. Workshop on Northern Hemisphere Sink. Princeton University, March 2-3, 1999.

Baldocchi, D. FLUXNET Overview, 1st IGBP-BAHC (Biosphere Aspects of the Hydrological Cycle Core Project) Synthesis Workshop, Obereggen, Italy. March 7-11, 1999.

Baldocchi, D. Modeling and Measuring CO_2 exchange over a Deciduous Forest in Undulating Terrain. Workshop on Nighttime Carbon Exchange, Local Divergence and Drainage Flow at Experimental Sites with Small Scale Topography. University of Indiana, Bloomington, IN, April 29-May 1, 1999.

Hollinger, D. FLUXNET and the AmeriFlux network. Workshop on carbon sinks. National Institute for Environmental Studies, Tsukuba, Japan. Mar. 18-19, 1999.

Hollinger, D. Preliminary results from the AmeriFlux network. NIGEC Northeast region annual meeting. Harvard Forest, MA. Mar. 30, 1999.

Meetings Attended:

Baldocchi, D, Hollinger, D. Olson, R. AmeriFlux Workshop, St. Louis, MO, Oct. 1997

Baldocchi, D., Valentini, R. Dahlem Workshop for Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. Berlin. Jan 18-23, 1998.

Baldocchi, D., Valentini, R. Euroflux Workshop, Sesto, Italy, Jan. 25-29, 1998

Baldocchi, D., Valentini, R. New Vistas in Transatlantic Science and Technology Cooperation, National Academy of Sciences, Washington, DC. June 8-9, 1998.

Baldocchi, D., E. Falge, D. Hollinger, R. Olson, S. Running, R. Valentini. FLUXNET Workshop, Polson, MT

Baldocchi, D. Hollinger, D. Workshop on Carbon Cycle Science Plan, August 18-19, 1998, Westminster, CO

Baldocchi, D., Falge, E., Hollinger, D., Olson, R. AmeriFlux Workshop, Harvard Forest, MA, Nov. 1998.

Baldocchi, D., Falge, E., Valentini, R. Euroflux Workshop, Hytialla, Finland, Dec., 1998.

Baldocchi, D., R. Valentini. 1st BAHC Synthesis Workshop.

Falge, E., Bayreuth University, EUROFLUX Modeling meeting. April, 1999.